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NDRC A-6

NATIONAL DEFENSE RESEARCH COMMITTEE

PROGRESS REPORT NO. A-6

OSRD #10

CONSTRUCTION OF THE NDRC EXPERIMENTAL FIRING RANGE AT PRINCETON UNIVERSITY

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by

H. D. Smyth

Chairman, Section S, Division A

[redacted]

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H. D. Smyth

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Approved for submission to Division Chairman

H. D. Smyth

H.D. Smyth, Author
Chairman, Section S, Div.A

Approved June 11, 1941
for submission to the Committee

Richard C. Tolman

Richard C. Tolman
Chairman, Division A

TABLE OF CONTENTS

I. INTRODUCTION

The purposes of this report are:

1. To account to the Committee for the expenditure of its appropriation;

2. To outline the principal activities to date of Section S, Division A;

3. To describe the facilities now available at Princeton University for the study of problems on terminal ballistics, or for carrying out tests of developments in the fields of passive protection and structural defense.

This report is pertinent to projects designated CE-5 and CE-6 by the War Department's NDRC Liaison Officer.

In response to a request from the Fortifications Section, Office of the Chief of Engineers, and under a contract between them and the National Academy of Sciences, the National Research Council set up in June of 1940 the Committee on Passive Protection Against Bombing (PPAB). As a part of the work of this Committee Professors Robertson and Bleakney of the Physics Department of Princeton University undertook theoretical and experimental investigations along these lines. It soon became apparent that one of their principal problems was the study of the penetration of projectiles into concrete. It was decided that this work could be accelerated by the provision of a firing range for the experimental investigation of penetration phenomena.

Staff members of the U.S. Naval Research Laboratory

and of the U.S. Naval Proving Ground indicated that their facilities were greatly overcrowded, and suggested that the establishment by NDRC of another range was desirable, in order to provide much needed additional experimental facilities for the study of penetration in armor plate.

To meet these needs of the Navy and PPAB, and of other contemplated activities, the National Defense Research Committee at its meeting on August 29,1940, approved in principal a contract with the Trustees of Princeton University for the construction of an experimental small arms range at Princeton.

On August 30,1940, Professor Smyth, Chairman of the Department of Physics at Princeton, conferred for the first time with Dr. Tolman, Chairman of Division A, National Defense Research Committee, concerning the project, and on September thirteenth presented the proposal to President Dodds of Princeton, who accepted it in principle. After various delays of a legalistic nature, the contract between the NDRC and the Trustees of Princeton University was signed on November 20, 1940. The contract, dated as of November 1,1940, provided for an expenditure of not more than $30,000, and instructed Princeton University to "conduct studies and experimental investigations in connection with the construction of a firing-range and the performance of tests on the penetration of small arms projectiles."

During October and November, before the contract was signed, Smyth, Robertson and Bleakney paid several visits to

the Naval Proving Ground, Naval Research Laboratory, and Aberdeen Proving Ground, where they received many valuable suggestions. It became evident that a number of changes from any existing range were desirable. Though complete plans of the range at Aberdeen and a sketch of the Naval Research Laboratory range were received by the Princeton group and were useful, the provisions of the contract reading "..... plans and specifications to be furnished by the Committee" was in fact not carried out.

II. PLANS AND ESTIMATES

The plans for the range were first discussed in detail at a meeting on November eleventh between Smyth, Robertson, Bleakney and Delsasso, representing the Department of Physics of Princeton University, and M.L. Beck, Architect, and E.R. Timby, Consulting Engineer. On November 17,1940, Mr. Beck submitted final design sketches. On November nineteenth these were discussed by the above group augmented by Dr. Irwin from the Naval Research Laboratory and Mr. MacMillan, Superintendent of the Department of Grounds and Buildings of the University. On December second working drawings were submitted to the Matthews Construction Company for estimate.

The estimate submitted December sixth was $27,965, not including architect's fees. As the result of further conference, a number of items was eliminated but it was evident that a very great reduction in cost would not be possible without

serious impairment of the usefulness of the range. On the other hand, it was clear that the original appropriation of $30,000 would be nearly used up by the construction and initial equipment of the range, leaving no funds for operation. This situation and the plans for the range were discussed by Dr. Smyth with Dr. Bush and Dr. Tolman on December second. They approved the plans and gave assurance that Princeton could expect additional funds to be made available, if needed, for running expenses of the range.

III. CONTRACT FOR CONSTRUCTION

On December fourth Princeton University placed an order with the Matthews Construction Company for the construction of the range at a cost not to exceed $24,500, under a Standard American Institute of Architects contract on the basis of net cost of labor and materials plus a fixed fee of $2,000. This did not include a fee of $1,000 for the services of the architect and consulting engineer.

IV. CONSTRUCTION

The Matthews Construction Company started work on December tenth. During the course of construction a number of minor modifications and additional features were suggested and incorporated. The building was accepted by the University on February 25,1941, although there remained some work on the road and fencing still to be done under the contract.

V. DESCRIPTION OF THE BUILDING

A. General

The building is located on level ground at the edge of the woods near the southeast corner of the University stadium (see Figures 1 and 2). This is an isolated location not on any approach to the stadium nor on any road other than an occasionally used field road which has been improved to make an approach to the range itself. Other than the stadium there are no buildings near. The distance to the Physics Laboratory is about half a mile, principally over private roads, so that frequent trips back and forth are not too serious an inconvenience.

The plans of the building followed almost automatically from the function it was required to fulfill. There had to be a target room connected to a firing room by an enclosed alley approximately a hundred yards long. In connection with the firing room there had to be some office, laboratory, and storage space because of the distance from the headquarters of the Department of Physics. The whole had to be planned for a maximum of economy and speed of construction but with great strength, at least at the target end, in order to satisfy requirements of safety. The resultant plan was a strictly utilitarian structure, reinforced concrete at the target end, frame sheathed with corrugated iron elsewhere (see pictures).

B. The Target Room

The target room itself is a chamber 12'8" square and

12'4" high. Behind it, separated by a partition partly timber and partly reinforced concrete, is a chamber 10' deep and the same width and height as the target room. This is filled with gravel and should unquestionably stop high velocity projectiles of caliber up to 37 mm, probably higher. The walls of this whole two compartment structure are reinforced concrete 12" thick. The floor and ceiling are also reinforced concrete 9" thick. In the ceiling is a manhole 6' x 2' which has already proved useful for vertical firing. The walls and ceiling of the target room are covered with a double layer of two inch planks to prevent chipping of the concrete.

Since one of the major uses planned for the range is the study of projectile penetration in concrete, equipment to handle heavy targets is essential. Partly to meet this need and partly for added safety, the end of the alleyway attached to the target room is of reinforced concrete and of the same height as the target room. Thus it was possible to continue the roof slab of the target room 24' along the alleyway and to bolt to its under side the rail for a travelling crane. On the sides the concrete walls are continued for 8', terminating in pillars which support garage-type doors 12'8" wide and 11'4" high. All this can be seen in the plan and in Figures 3, 4, 6, 7. When the doors are open, a truck can drive in under the crane; the target can be lifted off, run back into the target room, and lowered into position. Furthermore, there is a 36" light railway laid the length of the range and having a cross track through these doors and extending out

on concrete aprons on either side of the alleyway. This also facilitates the handling of targets, particularly discarded ones.

The only remaining features of this end of the range that need be described are the steel doors. These are of half inch steel and should be strong enough to stop reflected projectiles. Their position and general design are best seen in the plan and in Figure 6. The original plan and contract called for only one pair at the target room. Discussion with the Frankford group led us to add the second pair. Hinges are provided for still a third pair at the other side of the crossing doors as shown in the plan. There is already another pair of steel doors between the firing room and the alleyway (Figures 8 and 9).

C. The Alleyway

Between the target room and the firing room there must be a weathertight space large enough to serve readily as a passage, to allow for gun mounts for possible firing at ranges closer than 100 yards and to contain auxiliary equipment such as chronograph screens. These purposes are served by a corridor 8' wide and about 7' average headroom. The construction is heavy frame, sheathed inside with "gyplap", and outside with corrugated iron, aluminum painted. There are no windows, but there are top-hinged blinds on 24' centers to provide blast escape and cross ventilation when needed. The floor is cinder with the 36" railway laid on the cinder along the axis of the corridor.

D. The Firing Room, Office, Etc.

At the north end of the alleyway is the firing room. Space is required here for guns in current use, for chronographs, tools, and miscellaneous equipment. The dimensions, 17' x 17', were taken as small as seemed likely to satisfy the requirements. Already they are proving too small and some sort of additional storage space may have to be provided. To reduce the discomfort from noise the room was made 11' high and the walls were lined with 6" of rock wool. This has proved very satisfactory. The narrow gauge railway track extends through this room and ends on a concrete apron. As shown in Figures 1 and 5, the firing room opens on to this apron with a garage-type door. This makes it easy to bring in bulky equipment and will also make it possible to fire at ranges slightly greater than a hundred yards by moving the gun out into the open and firing through the open door of the firing room.

There is a pair of half inch steel doors between the firing room and the alleyway with a hole through which the muzzle of the gun projects as shown in Figures 8 and 9. This door is normally left closed and the alleyway reached through the door into the passage as can be seen in the plan. The firing room has a reinforced concrete floor but otherwise is of frame construction.

As can be seen from Figures 1, 2, 5, 10, and 11, there is a small building attached to the west side of the firing room. This building is of light frame construction. It contains a

corridor, lavatory, small dark room and office 11' x 15'. This office serves also as a loading room and as a bedroom for the night guard, one of the enlisted men from the R.O.T.C. unit at Princeton.

VI. THE GUNS

As the most important items of the range equipment, the guns now available are listed in Table I, below. Because of the dual organization of the Princeton group, and because of the different procedures which were necessary in acquiring these guns, the owner or consignee is given in each case.

In order to obtain data of improved distribution and range in both calibre and velocity, a 20 mm. gun (aircraft cannon) and a 37 mm. high velocity anti-tank gun are needed. Because of the limited numbers of these available, and because of the unfilled needs for these guns for combat units, they are not yet included in the range equipment.

TABLE I

Guns Available at NDRC Range, as of June 1,1941

Number Available	Caliber	Type	Ownership
1	0.257 in.	Remington Roberts	Purchased by Section S, Div. A, NDRC
1	0.30 in.	1903 Springfield Complete	Purchased by PPAB
2	0.30 in.	1903 Springfield Barrels only	Purchased by Section S, Div.A, NDRC
1	0.30 in.	Mann Type Barrel with receiver	Consigned by Ordnance Dept. to Military Property Custodian Princeton University
1	0.45 in.	1863 .45-70 Springfield complete	Purchased by PPAB
1	0.45 in.	1863 .45-70 Springfield complete	Purchased by Section S, Div.A, NDRC
1	0.45 in.	Colt Army Pistol	Purchased by PPAB
1	0.50 in.	Heavy Machine Gun Barrel, with breech made in Dept. of Physics Shop	Consigned by Ordnance Dept. to Military Property Custodian, Princeton University
1	1.1 in.	Navy Machine Gun 1936 with breech and recoil mechanism. Mount constructed in Dept. Shop	Consigned by Naval Gun Factory to H.D. Smyth, Chairman, Section S, Div. A, NDRC
1	37 mm.	Model 1916 Low Velocity ("one pounder") complete with carriage	Transferred from Section T to Section S, Div. A, NDRC

VII. OTHER EQUIPMENT

Three movable cars are available for use on the track. One, bought through the contractor, is shown in Figure 6. It is used for moving heavy targets and equipment. A second, built in the department shops, is shown in Figures 8 and 9 carrying the caliber .30 and .50 gun mount. It is equipped with a brake which expands against the rails, locking the car in firing position. A third very light car constructed in the department shops is used for light equipment such as chronograph screens.

The gun mount for the caliber 0.30 and caliber 0.50 barrels is shown in Figures 8 and 9. It was constructed in the department shops patterned approximately after the mounts used at Frankford, Aberdeen and elsewhere but using channel iron instead of castings. This change effected considerable economy of time and money. The mount is entirely satisfactory. The telescope fixed on the mount has been borrowed from the Department of Physics. The 1.1 gun and the 37 mm. gun are mounted, but photographs of them are not yet available.

For measuring velocities an Aberdeen chronograph is used. This was built in the laboratory by Professor Bleakney and is described in moderate detail in a recent report to the PPAB.*

Other items of equipment include an intercommunication system between the firing room and the target room, pneumatic

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* Terminal Ballistics II, An Experimental Study of Penetration in Concrete, by W. Bleakney and R.A. Beth. Delivered May 7, 1941 to Fortifications Section, Office of the Chief of Engineers, U.S. Army.

firing apparatus, a steel screen in the firing room and, on the outside door in the alleyway near the target room, a safety catch which has to be released at the firing room. A minimum of furniture has been bought, including stools, a day-bed for the night guard, and so forth. The office building and firing room are heated by a small fuel oil heating unit in the corridor. There is no heat in the alleyway or target room.

- As an additional safety measure two duPont field magazines have been purchased and set up inside the fenced enclosure. They have ample capacity for present or probable supplies of ammunition and explosives.

VIII COSTS OF CONSTRUCTION, EQUIPMENT AND OPERATION TO May 31,.1941

The final bill submitted by the Matthews Construction Company, certified by the architect and paid by the University, brings the cost of construction to a total of $23,935.98, representing a saving of over $500 on the maximum cost ($24,500) stipulated in the original order. This is particularly gratifying since the bill as rendered included an extra pair of steel doors ($345.00) and a number of small items not in the original specifications. An informal account of costs to date of May 31,1941 is given in tabular form below. The exact accounting is, of course, made by the Bursar of the University.

Construction of the Range including road, fencing and so forth	$23,935.98	
Fee to Architect and Consulting Engineer	1,000.00	
Total Cost of Construction		$24,935.98
Tools, equipment, material already paid for	1,077.67	
Wages already paid	1,100.50	
Tools, equipment, and so forth on order	201.97	
Total for tools, and so forth, and labor		2,380.14
Total of our ledger transactions	$27,316.12	
50% overhead on wages		550.25
Armor arranged for through Naval Research Laboratory but not formally ordered		400.00 (appr.)
Total payments and obligations as of May 31,1941		$28,266.37

IX. CURRENT AND CONTEMPLATED OPERATIONS

Before the NDRC Range was available, the Committee on PPAB carried out penetration experiments in the Physics Laboratory. These were necessarily restricted to calibres of 0.30 and 0.45 inches. The facilities used for these experiments will remain available, if needed to relieve overloading of the new range. The smaller guns, chronographs, and other portable equipment can be used in either place.

With the completion of the NDRC Range, it became possible to extend the experimental activities of PPAB to include calibres up to 37 mm. By firing a 37 mm. gun down through the manhole in the roof of the target room, at a horizontal concrete slab, and subsequently detonating appropriate charges of explosive in the craters, it has been possible to obtain data on the separate phenomena of penetration and detonation, and on the reaction forces produced in the slab and its supports. This work is still in progress.

In informal cooperation with Frankford Arsenal, Section S is carrying on research on a few special problems in connection with penetration of armor plate. A report on one of these problems is nearly completed. Some tests are being conducted on the penetration characteristics of special materials under development as possible substitutes for armor.

Conferences with Army and Navy representatives have been held in order to coordinate the armor research at Princeton with that of the Watertown Arsenal, Naval Research Laboratory, and Naval Proving Ground.

Personnel and organizations concerned, and the suggested allocation of research, are indicated in the following memorandum:

MEMORANDUM ON CONFERENCE AT PRINCETON

May 24, 1941

By H.D. Smyth, Chairman of Section S
and other members of the Conference

A Conference called to discuss correlation of research on armor was held in the Palmer Physical Laboratory of Princeton University on May 24,1941, and was attended by

Col. Ritchie (Watertown Arsenal), Lt. Col. Dix (Office Chief of Ordnance), Capt. Atkins (Office Chief of Ordnance), Dr. Reed (Watertown Arsenal):

Dr. Irwin (Naval Research Laboratory), Dr.Thompson (Naval Proving Ground), Mr. Wertheimer (Bureau of Ordnance);

Dr. Bleakney, Dr. Delsasso, Dr.Robertson, Dr. Smyth (Princeton University).

The Conference agreed upon the following.

SUMMARY OF SUGGESTED ALLOCATION OF RESEARCH ON ARMOR

AMONG THE FOLLOWING GROUPS

NAVAL RESEARCH LABORATORY

Energy and mechanics of penetration in various materials, with emphasis on limit velocity and below, up to and including 37 mm. Laboratory size tests of plate quality. Light armor for aircraft.

PRINCETON UNIVERSITY

Energy and mechanics of penetration in various materials, with emphasis on velocity above limit, up to and including 37 mm. Reaction of plate as a whole, with special reference to supporting system and vibrations. In addition, collaboration with the National Research Council on problems of passive protection against bombing.

NAVAL PROVING GROUND

General study of factors affecting armor uniformity. Parallel program of ballistic tests and of studies of all relevant physical and chemical characteristics of materials, mainly at 3 inch projectile scale and larger. This program complements the Watertown Arsenal program on lighter gauge plate.

WATERTOWN ARSENAL

Continuation of present program of research and development of light armor, with special emphasis upon the metallurgical aspects. This program includes problems of correlation of metallurgical, physical, and ballistic properties, with a view to the development of maximum ballistic performance.

As part of this program, samples of armor plate from the Naval Proving Ground and Naval Research Laboratory, some of which will have been through their shooting tests, will be sent to the Princeton Range for penetration tests, to secure data for comparison with those obtained by the Navy, and to study the variation in test results at different points on the plates under various conditions of plate support.

The supplementing of the existing facilities of the Army and Navy for research on armor, and the aiding of these agencies in the more rapid solution of their most pressing problems, are regarded as important functions of the NDRC Range. It is contemplated, however, that personnel and facilities will be available for additional problems originating within the NDRC organization.

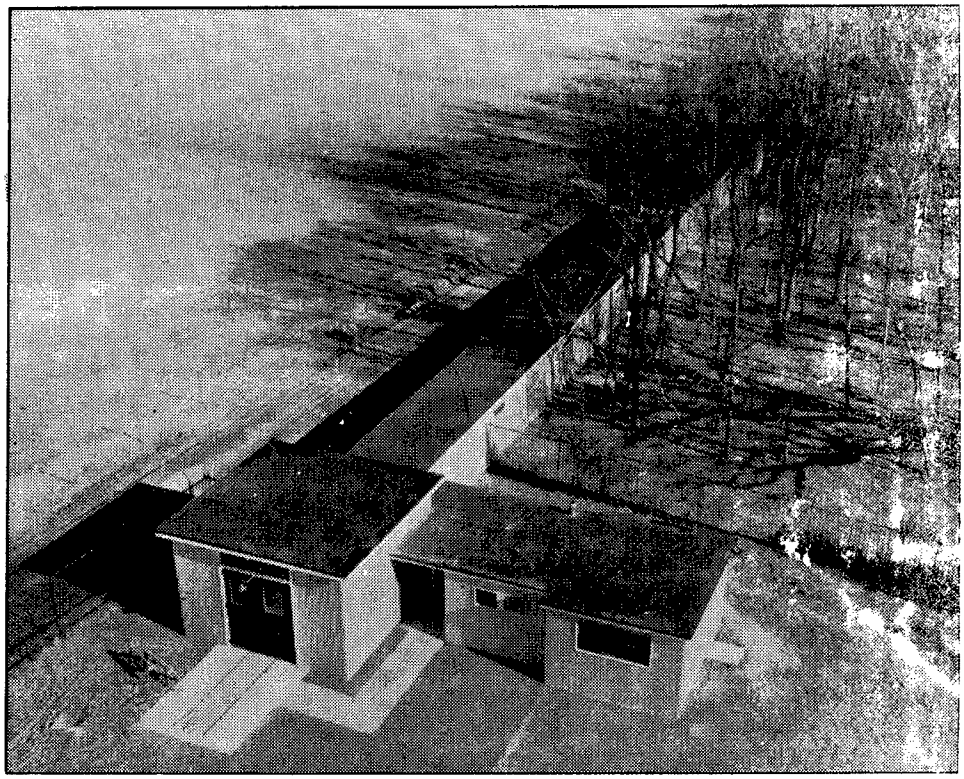


Figure 1

Air view

Firing room end

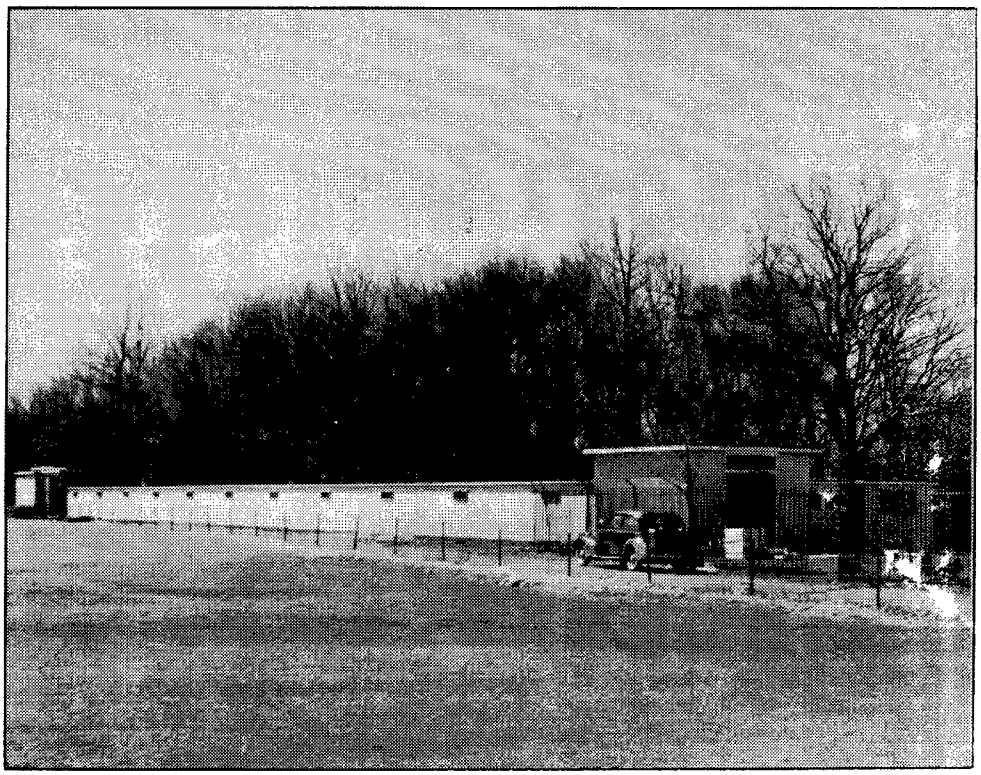


Figure 2
General view from East
Firing room at right

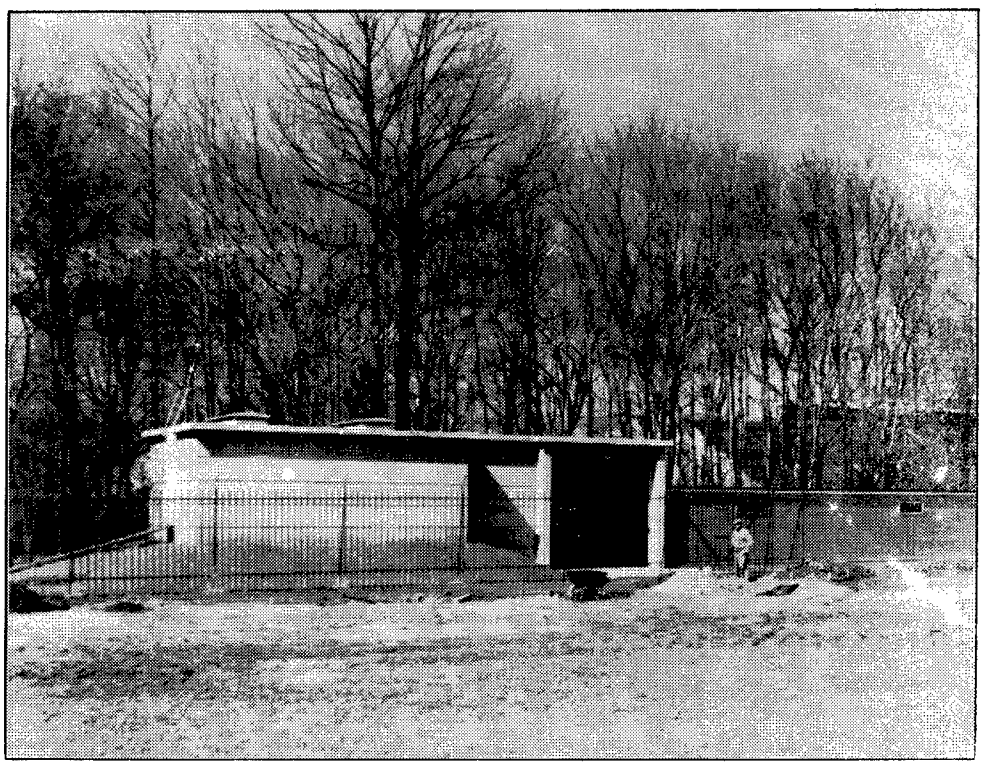


Figure 3
Target room from East

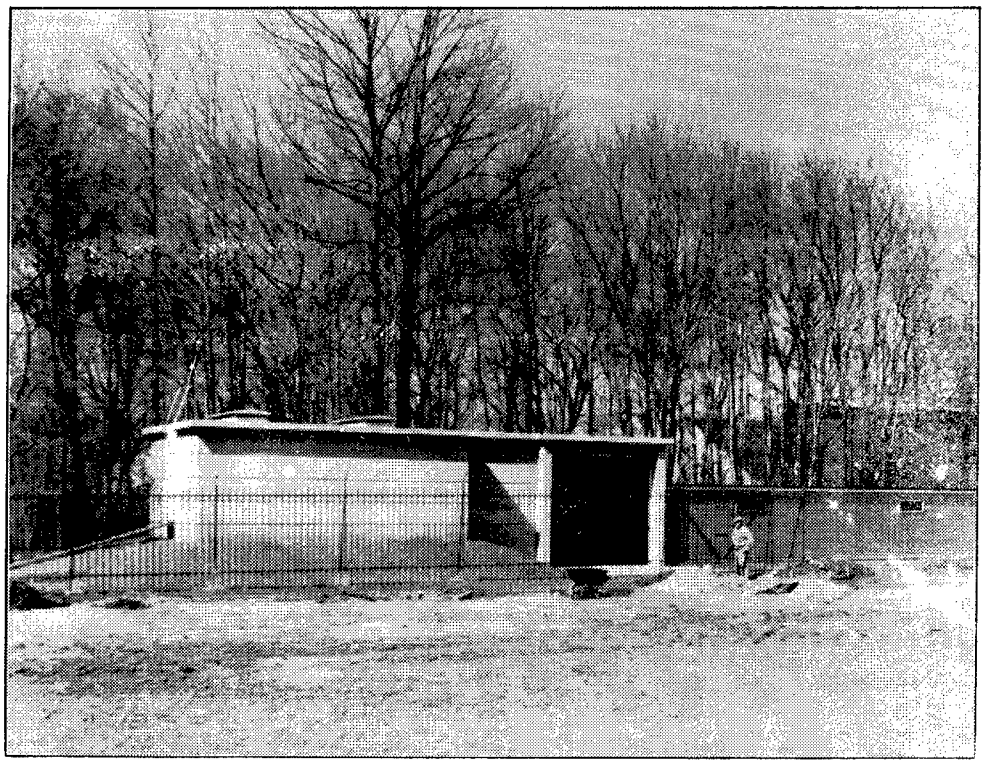


Figure 3
Target room from East

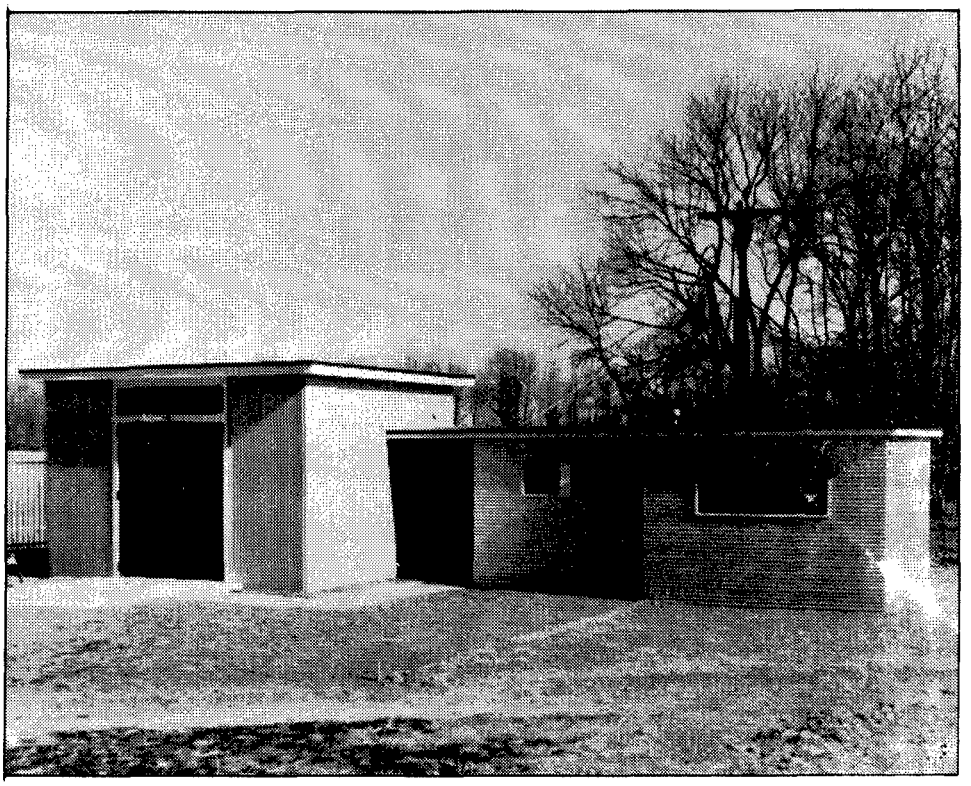


Figure 5

Firing room and Office from the North

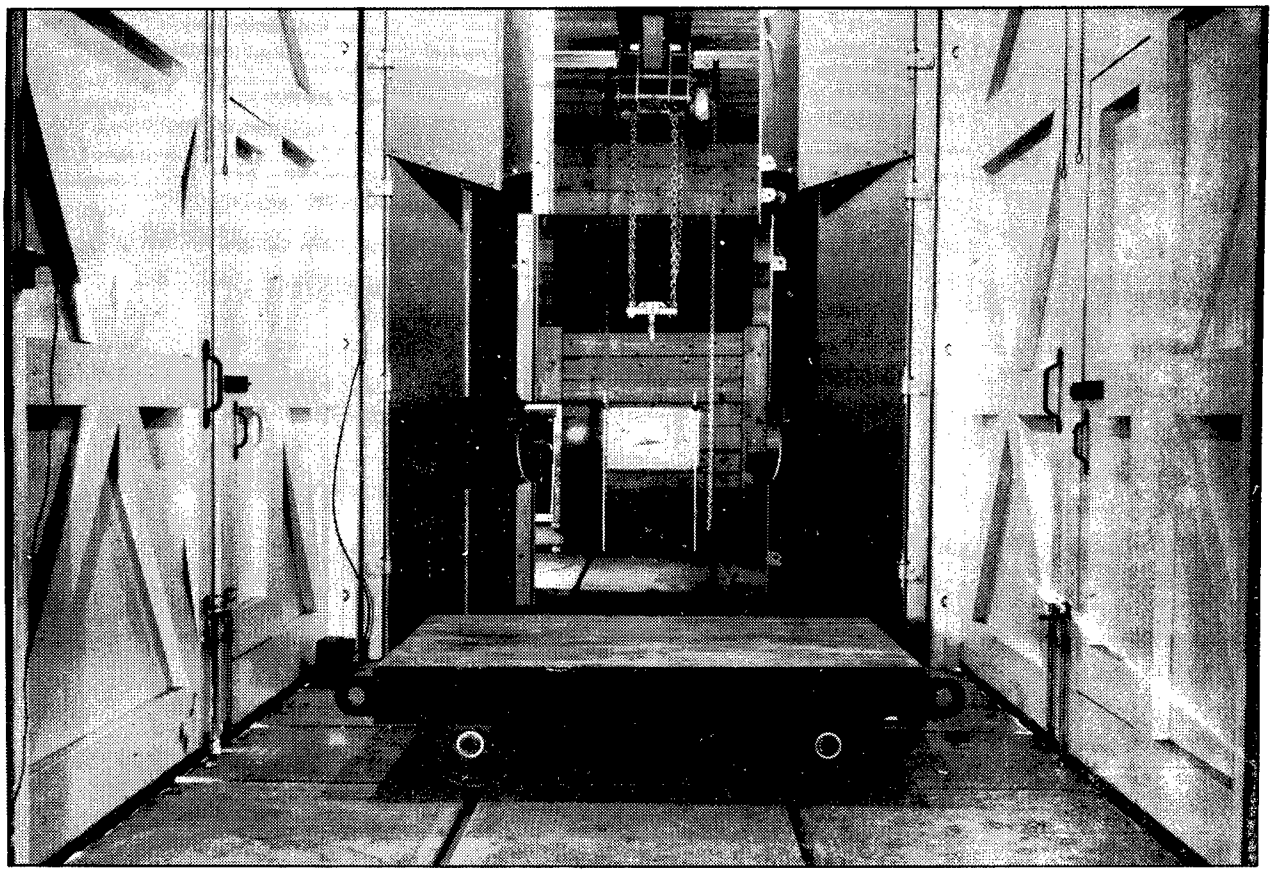


Figure 6

Target end of alley

looking into firing room

Figure 7
Doors and crosstrack
at target end of alley

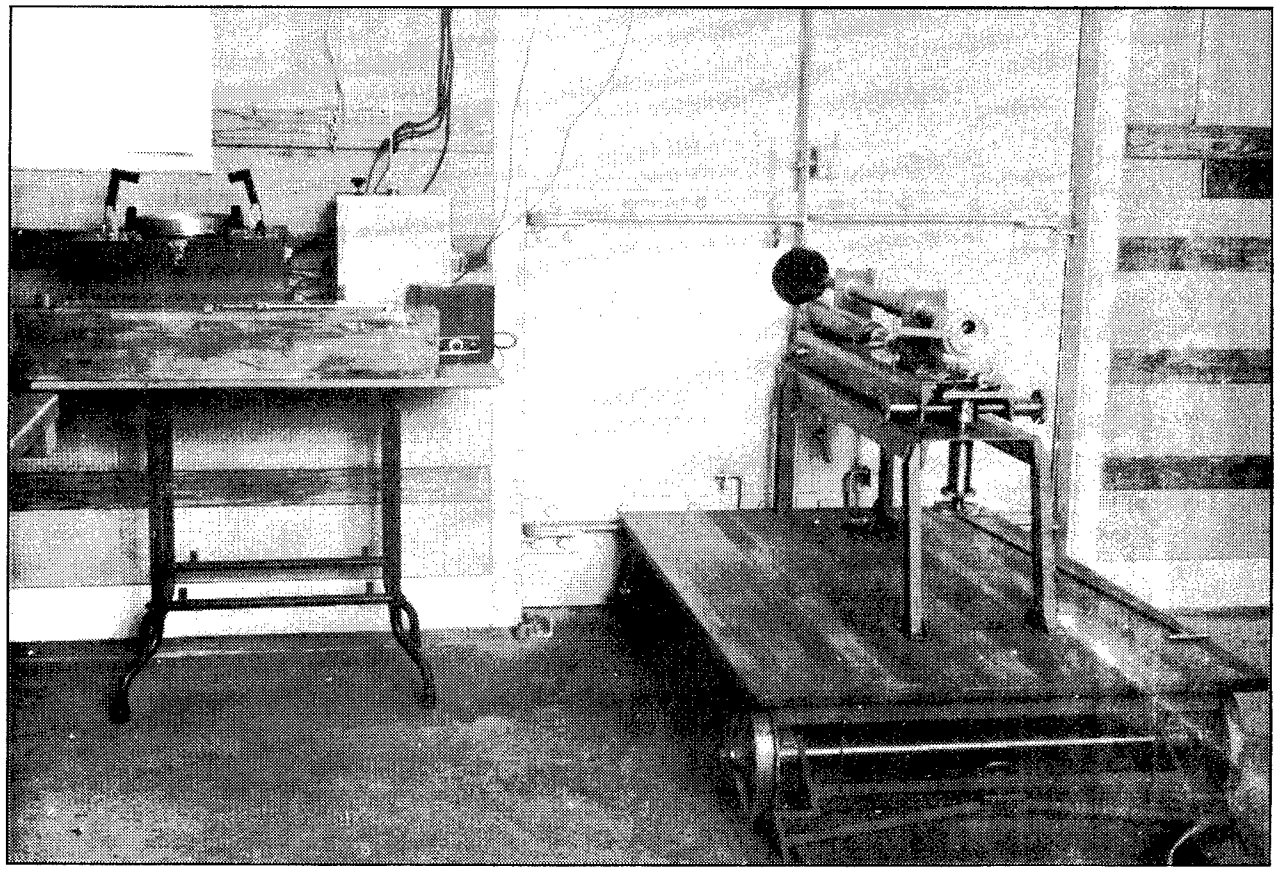


Figure 8
Firing Room
with gun mounted
in firing position

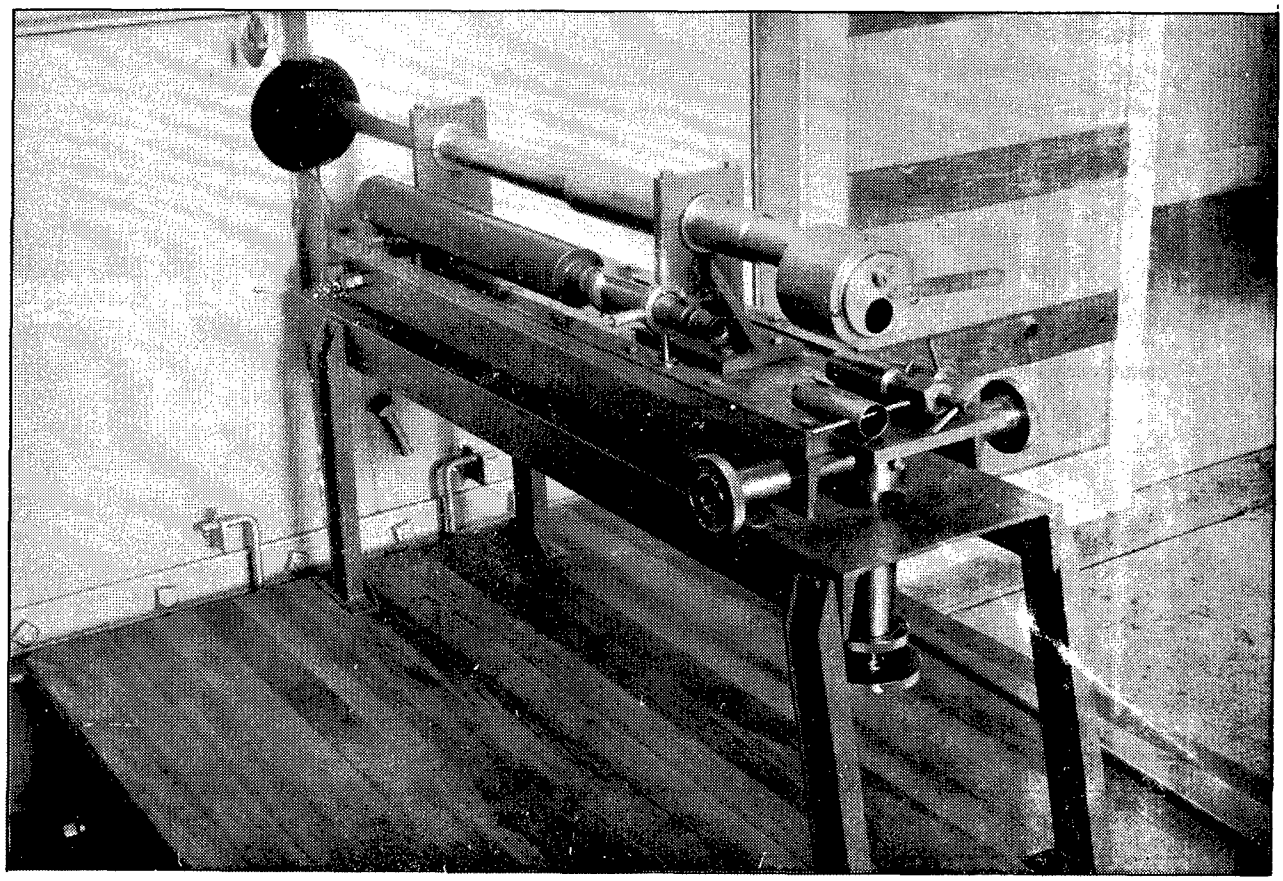
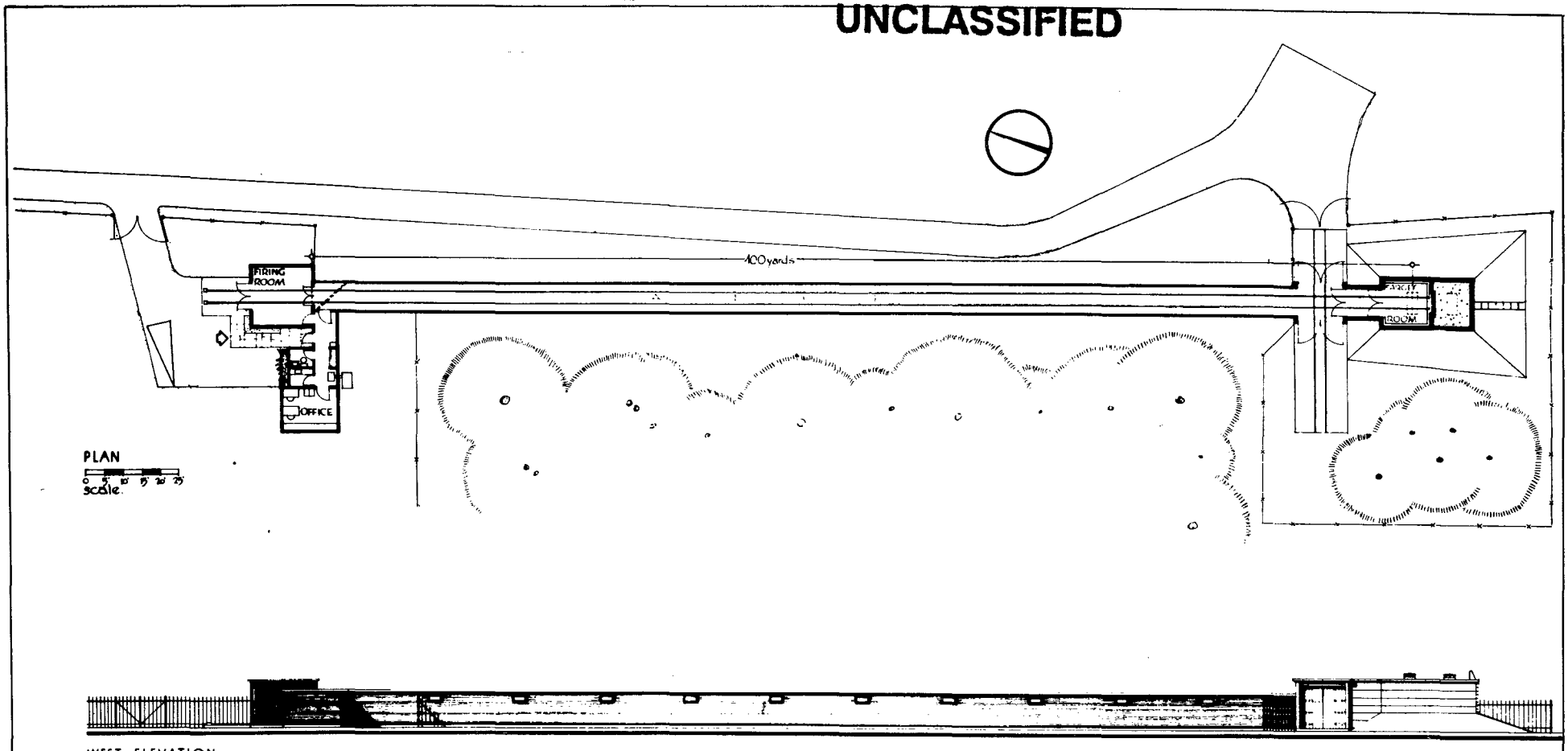


Figure 9
Close-up of gun mount



N. D. R. C. LABORATORY RANGE AT PRINCETON UNIVERSITY ... DESIGNED BY M. L. BECK, ARCHITECT AND E. K. TIMBY ENGINEER

Figure 10

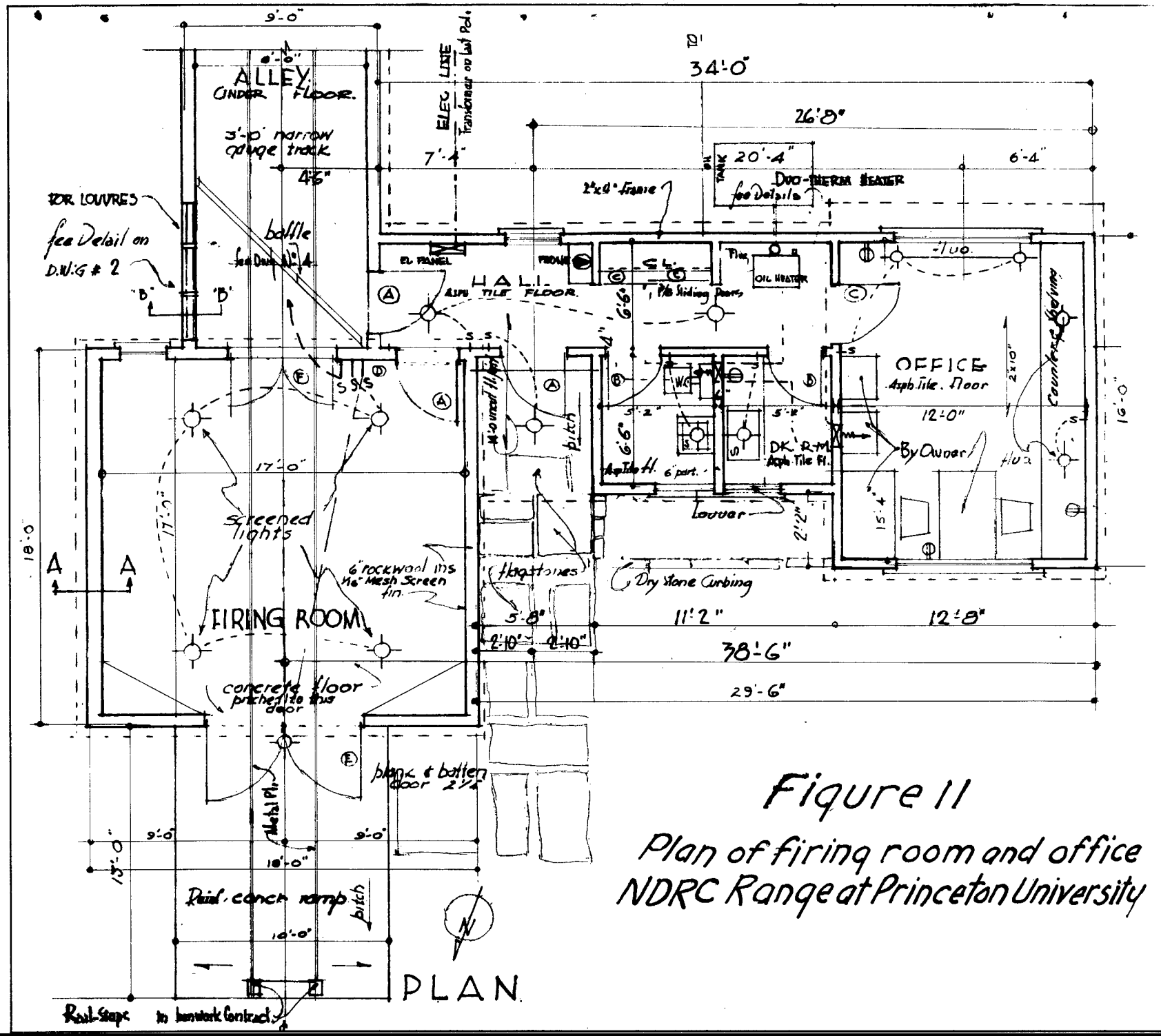


Figure 11

Plan of firing room and office
NDRC Range at Princeton University